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DEVELOPMENT OF A CHEMO-ENTREPRENEURSHIP BASED CHEMISTRY PRACTICUM E-MODULE USING THE PROJECT BASED LEARNING MODEL ON COLLIGATIVE PROPERTIES OF SOLUTIONS

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ABSTRAK

Pembelajaran kimia tidak hanya menekankan pemahaman konsep, tetapi juga memerlukan kegiatan praktikum agar peserta didik dapat memahami materi secara konkret dan kontekstual. Namun, bahan ajar di SMAN 1 Patianrowo masih didominasi oleh buku paket, dan keterbatasan alat serta bahan praktikum menyebabkan kegiatan praktikum kimia jarang dilaksanakan, sehingga keterlibatan peserta didik dalam pembelajaran, khususnya pada materi sifat koligatif larutan, masih rendah. Penelitian ini bertujuan untuk mengembangkan *e-modul* praktikum kimia berbasis *chemo-entrepreneurship* dengan model *project-based learning* pada materi sifat koligatif larutan. Produk berupa *e-modul* yang dipublikasikan melalui *platform* Heyzine Flipbook mengintegrasikan pendekatan *chemo-entrepreneurship* dengan sintaks *project-based learning* melalui proyek pembuatan es krim, sirup buah, permen gummy, dan manisan buah. *E-modul* juga memuat analisis *Break-Even Point* (BEP), *Strengths, Weaknesses, Opportunities, Threats* (SWOT), serta *QR Barcode* interaktif untuk mengakses video demonstrasi, materi pendukung, latihan soal, dan evaluasi pembelajaran. Penelitian ini menggunakan metode *Research and Development* dengan model pengembangan 3D (*define, design, develop*). Sampel penelitian terdiri atas 36 peserta didik kelas XII-1. Hasil penelitian menunjukkan *bahwa e-modul memperoleh kategori sangat valid dari ahli materi (83,28%) dan ahli media (83,12%), sangat praktis berdasarkan respons peserta didik (85,48%), serta cukup efektif dalam* meningkatkan hasil belajar dengan persentase N-Gain sebesar 56%.

ABSTRACT

Chemistry learning emphasizes not only conceptual understanding but also laboratory activities to help students comprehend concepts in a concrete and contextual manner. However, learning materials at SMAN 1 Patianrowo are still dominated by printed textbooks, while limited laboratory equipment and materials have led to infrequent implementation of chemistry practicum activities. Consequently, students' engagement in learning, particularly on the topic of colligative properties of solutions, remains low. This study aimed to develop a chemo-entrepreneurship-based chemistry practicum e-module using the Project-Based Learning model on the topic of colligative properties of solutions. The product is an e-module published through the Heyzine Flipbook platform, integrating the chemo-entrepreneurship approach with the Project-Based Learning syntax through projects involving the production of ice cream, fruit syrup, gummy candy, and candied fruit. The e-module also includes Break-Even Point (BEP) calculations, Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, as well as interactive QR codes providing access to demonstration videos, supplementary learning materials, practice exercises, and learning evaluations. This study employed the Research and Development (R&D) method using the 3D development model (Define, Design, and Develop). The research sample consisted of 36 twelfth-grade students in Class XII-1. The results indicated that the developed e-module was categorized as highly valid based on material expert validation (83.28%) and media expert validation (83.12%), highly practical according to students' responses (85.48%), and moderately effective in improving learning outcomes, with an N-Gain score of 56%.

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INTRODUCTION

21st-century education demands that students develop critical, creative, collaborative, and communicative thinking skills to address the increasingly rapid developments in science and technology. The implementation of the Independent Curriculum encourages student-centered learning through contextual and meaningful learning experiences (Laliyo et al., 2023). However, these demands are not fully aligned with the scientific literacy achievements of Indonesian students. The 2022 Program for International Student Assessment (PISA) results showed that Indonesian students' scientific literacy score was 383, lower than the score of 485 in other Organization for Economic Co-operation and Development (OECD) countries (OECD, 2023). This low achievement indicates that Indonesian students still have difficulty applying scientific concepts, including those in chemistry, to explain phenomena and solve real-life problems.

These difficulties are evident in chemistry lessons, particularly in the topic of colligative properties of solutions. Research by Winiawati and Hernani (2023) conducted with 12th-grade students at a high school in Garut Regency showed that students' conceptual understanding of the increase in vapor pressure was relatively low: only 41.67% fully understood the concept, while the remaining 50% did not understand it at all. The most prominent difficulty lay in connecting solution concentration with mass and volume quantities, and linking the Van't Hoff factor to the appropriate colligative quantities. Similar findings were also reported by Auliyani et al. (2018), who used a three-tier multiple-choice diagnostic test on 12th-grade science students in Banda Aceh and found a high level of misconceptions regarding the colligative properties of solutions. These findings indicate that difficulties with the colligative properties of solutions remain a common problem in chemistry learning.

The colligative properties of solutions are closely related to various phenomena in everyday life, so learning needs to be supported through practical activities. Lab work provides hands-on learning experiences that help students observe, analyze, and connect the concepts of colligative properties of solutions with their real-life applications. Thus, students not only understand the concepts theoretically but also develop a more meaningful understanding through the process of scientific inquiry. Furthermore, lab work can enhance students' thinking skills, motivation, and interest in chemistry (Sayyidatuzzahrah et al., 2025).

Based on a needs analysis conducted at SMAN 1 Patianrowo through interviews with chemistry teachers, learning about the colligative properties of solutions is still dominated by textbooks and conventional teaching materials. The learning model used is still teacher-centered. Furthermore, chemistry learning on the colligative properties of solutions rarely includes practical activities, even though they are an important tool for helping students understand chemical concepts and connect them to phenomena occurring in everyday life. The lab work is also not supported by engaging, interactive, and easily accessible teaching materials. A similar problem was also found by Fitri et al. (2022), who stated that limited practical modules and learning support facilities made it difficult for students to grasp chemical concepts, resulting in low comprehension of the material. This situation indicates the need to develop innovative teaching materials that can support practical activities, connect chemical concepts to everyday life, and encourage active student involvement in the learning process.

The development of digital technology provides opportunities to develop more innovative teaching materials through e-modules. E-modules are electronic teaching materials that can combine text, images, videos, animations, and interactive activities to support students' independent learning (Ramadhan et al., 2025). Practical e-modules function not only as learning resources but also as guides for practical implementation, containing systematic activity instructions and linking the chemistry concepts learned to real-life situations. Furthermore, e-modules can be flexibly accessed through digital devices, thus supporting more effective learning and practical implementation (Herawati & Muhtadi, 2018). In this study, the developed practical e-modules were published through the Heyzine platform, which supports online access to teaching materials, making them easily accessible through electronic media.

The development of practical e-modules in this study was integrated with the Chemo-Entrepreneurship (CEP) approach. The chemo-entrepreneurship approach is a learning framework that connects chemical concepts to the processing of materials into products with utility and economic value. This allows students not only to understand chemical concepts but also to gain entrepreneurial insight (Runtuwene et al., 2025). Chemo-entrepreneurship-based learning can encourage students to connect the material learned with real-life experiences and foster creativity, innovation, and entrepreneurial interest (Milaningsih et al., 2023). In the topic of colligative properties of solutions, the chemo-entrepreneurship approach can be applied through the creation of products related to the concepts of freezing point depression, boiling point elevation, and osmotic pressure, enabling students to understand the application of chemical concepts in everyday life.

In addition to the chemo-entrepreneurship approach, this research also integrates the Project-Based Learning (PjBL) model. Project-based learning is a student-centered learning model through project activities designed to solve a problem or produce a product (Ling et al., 2024). Through the project-based learning model, students are actively involved in the investigation, design, implementation, and evaluation of projects, thereby developing critical thinking, creativity, communication, and collaboration skills (Qiara, 2024). This model aligns with the characteristics of the Independent Curriculum, which emphasizes active and contextual learning. The project-based learning model also provides opportunities for students to construct their knowledge through direct experience, making learning more meaningful and oriented toward solving real-world problems.

The integration of the Chemo-Entrepreneurship (CEP) approach and the Project-Based Learning (PjBL) model is considered relevant because both emphasize active student involvement in the learning process and the production of useful products. Chemo-entrepreneurship connects chemical concepts to everyday life by creating economically valuable products, while project-based learning facilitates students' learning through a series of systematic project activities, from planning and implementation to evaluation. Through this integration, students not only gain a more meaningful understanding of concepts but also gain hands-on experience in applying chemical concepts to solve real-world problems in their environment. Furthermore, project activities integrated with entrepreneurial values can foster the development of critical thinking skills, creativity, collaboration, communication, and an entrepreneurial spirit, all essential components of 21st-century competencies. Therefore, the combination of the chemo-entrepreneurship approach with the project-based learning model has the potential to create chemistry learning that is more contextual, innovative, and oriented toward holistic student skill development.

Although various studies have developed electronic teaching materials and chemo-entrepreneurship-based teaching materials, there has not been any research that specifically integrates the Chemo-Entrepreneurship (CEP) approach with the Project-Based Learning (PjBL) model in the development of e-practicum modules on the colligative properties of solutions. In addition, there are not many practicum teaching materials specifically designed to help students connect the concept of colligative properties of solutions with their application in everyday life through project activities that produce useful products and have not integrated entrepreneurial analysis. Therefore, it is necessary to develop teaching materials in the form of e-practicum modules using the chemo-entrepreneurship approach with a project-based learning model on the colligative properties of solutions that can support practicum activities, increase student involvement in learning, and connect chemical concepts with real-life contexts. This study aims to develop Chemo-Entrepreneurship-based E-Practical Module teaching materials with the Project-Based Learning Model on the colligative properties of solutions and to determine the level of validity, practicality, and effectiveness.

METHODS

The research method used in developing the chemistry practicum e-module was Research and Development (R&D) using the Thiagarajan 4D development model adapted into 3D: define, design, and develop (Handayani & Suharyanto, 2016). The dissemination stage was not conducted due to time and scope limitations. This model was chosen to achieve a valid, practical, and effective product. The stages involved were the define stage, encompassing needs analysis, student analysis, concept analysis, task analysis, learning objectives analysis, and chemo-entrepreneurship analysis. The design stage involved drafting a chemo-entrepreneurship-based chemistry practicum e-module using a project-based learning model on the colligative properties of solutions. The development stage encompassed the product development process, validation by material and media experts, product revision, analysis of student responses, and limited student trials (Safitri & Sari, 2022).

Data collection techniques in this study included interviews, questionnaires, and expert validation. Interviews were conducted with chemistry teachers at SMAN 1 Patianrowo to obtain information regarding the needs, problems, and use of teaching materials in the chemistry learning process. Next, a questionnaire was distributed to 12 students in grade XII-1 to analyze student needs, including learning styles, learning interests, and obstacles encountered during the chemistry learning process. The results of the interviews and questionnaire analysis were used to develop a practical e-module that suits students' characteristics and learning needs. Product validation was carried out by two validators consisting of one Chemistry lecturer and one high school Chemistry teacher. Both validators acted as both material experts and media experts. The selection of validators was based on competency in the fields of chemistry science, development of learning media and teaching materials, and chemistry education research. The selection of validators took into account the relevance of their fields of expertise and professional experience so that the assessments could serve as a basis for revising and refining the e-module before conducting a limited trial (Grant & Davis, 1997).

The population in this study was all 12th-grade students at SMAN 1 Patianrowo. The sample was selected using a purposive sampling technique, which involves selecting a sample based on specific considerations consistent with the research objectives. Based on this technique, the sample was determined to be one class, class XII-1, with 36 students. Class XII-1 was selected based on the consideration that students in this class had studied the colligative properties of solutions, possessed characteristics consistent with the e-module development objectives, and were recommended by the chemistry teacher as a representative class for conducting a limited trial. Therefore, class XII-1 was deemed to meet the criteria for providing information regarding the practicality and effectiveness of the developed e-module. Practicality was measured using a student response questionnaire, while effectiveness was assessed through pretest and posttest results using the N-Gain test to determine the impact of the developed chemistry practicum e-module on student learning outcomes.

The instrument used to test the product validity was a validation questionnaire from material experts and media experts (Mufida et al., 2022). A student response questionnaire was used to measure the practicality of the e-module. Data from expert validation results and student responses to the chemistry practicum e-module were analyzed using a Likert scale with 5 categories, namely 5 (very good), 4 (good), 3 (fairly good), 2 (not good), 1 (very bad). The instrument used to test the level of effectiveness of the chemistry practicum e-module to improve student learning outcomes is in the form of pretest and posttest question instruments consisting of 10 essay questions with cognitive levels C2-C5 that have been validated by media experts and material experts. The following table shows the validity of the expert instruments, student responses, and pretest-posttest question grids.

Table 1. Media expert validation instrument grid

Aspect	Indicator	Item number
Kegrafikan	Ukuran *e-modul*	1,2,3,4,5
	Desain sampul	6,7,8,9,10,11
	Desain isi *e-modul*	12,13,14,15,16
Pengoperasian	Kemudahan penggunaan	17,18,19,20

Source: Depdiknas (2008)

Table 2. Grid of material expert validation instruments

Aspect	Indicator	Item number
Content	Suitability of learning outcomes and flow of learning objectives with the material	1,2,3
	Suitability of material	4,5,6,7
	Compliance with the concept of chemo-entrepreneurship	8,9
Displays	Suitability of presentation techniques	10,11
	Suitability of presentation support	12,13,14,15,16,17,18,19,20
Language	The language presented is straightforward	21,22,23
	The language presented is communicative	24,25

Source: Depdiknas (2008).

Table 3. Student response questionnaire grid

Aspect	Indicator	Item number
E-Module Appearance and Design	Attracting students' interest	1
	Presented in color and with pictures	2, 3
Practicality of Material	Compliance with school materials	4, 5
Learning Objectives and Process	Clarity of learning objectives	6, 7
	Clarity of learning steps	8, 9
Language and Presentation of Questions	Clarity of questions	10, 11
Motivation and Learning Engagement	Raising learning motivation	12, 13
Higher Order Thinking Skills	Encourage problem solving	14, 15
	Guiding critical thinking	16, 17
Chemo-Entrepreneurship	Application of chemical concepts in the business world	18
	The relationship between practical work and business opportunities	19
	Development of products with economic value	20

Source: Adapted and modified from BSNP (2014), Asyhar (2012), Keller (2010), Ennis (2011), and Supartono (2006).

Table 4. Grid of pretest-posttest questions

Topic of the Material	Achieved Competency Indicators	Item Indicator	Cognitive Level	Item Number
The Concept of Colligative Properties of Solutions	Students can explain the meaning of colligative properties of solutions.	Through descriptive questions, students can correctly explain the meaning of colligative properties of solutions.	C2	1

Topic of the Material	Achieved Competency Indicators	Item Indicator	Cognitive Level	Item Number
Types of Colligative Properties of Solutions	Students are able to identify various colligative properties of solutions.	Given written questions, students can correctly identify and explain the various colligative properties of solutions.	C2	2
Application of Colligative Properties of Solutions	Students are able to relate the concept of colligative properties to everyday life.	Through contextual questions, students can appropriately relate the concept of colligative properties of solutions to everyday phenomena.	C3	3
Boiling Point Elevation of Solution	Students are able to analyze the effect of solutes on the boiling point of solutions.	Based on the results of the practicum, students are able to analyze the effect of dissolved substances on the increase in the boiling point of the solution correctly.	C4	4
Mole Fraction	Students are able to calculate the mole fraction of a solute.	Given the mass data for the solute and solvent, students can systematically and accurately calculate the solute's mole fraction.	C3	5
Decrease in Vapor Pressure of Solution	Students are able to calculate the decrease in vapor pressure of a solution.	Given vapor pressure data and solution composition, students can correctly calculate the solution's decrease in vapor pressure.	C3	6
Decrease in Vapor Pressure of Solution	Students can evaluate the results of experiments on reducing the vapor pressure of solutions.	Based on the experimental data, students are able to evaluate the suitability of the experimental results with the theory of reducing the vapor pressure of solutions, accompanied by appropriate reasons.	C5	7
Boiling Point Elevation of Solution	Students are able to determine solutions to problems related to the increase in the boiling point of solutions.	Based on the problems presented, students are able to determine appropriate solutions based on the concept of increasing the boiling point of a solution correctly.	C5	8
Osmotic Pressure	Students are able to explain the concept of osmotic pressure contextually.	Based on the reading presented, students are able to analyze the role of osmotic pressure in making gummy candies and candied fruit correctly.	C4	9
Application of Colligative Properties to CEP Products	Students are able to analyze the application of the concept of colligative properties of solutions in the products they make.	Based on the project product, students are able to analyze the application of the concept of colligative properties of solutions that play a role in the product manufacturing process appropriately.	C4	10

The implementation of the chemistry practicum e-module was analyzed based on the obtained data, including the product's validity and practicality. This analysis was conducted to provide meaning and decision-making based on percentage assessment criteria. A product validity level of 81–100% is categorized as very valid, 61–80% as valid, 41–60% as less valid, 21–40% as invalid, and below 20% as very invalid (Arikunto, 2013). A practicality level of 81%–100% is categorized as very practical, 61–80% as practical, 41–60% as less practical, 21–40% as impractical, and below 20% as very less practical (Widoyoko, 2025).

Improvement in learning outcomes was measured using the N-Gain value, defined as the difference between the pretest and posttest scores (Pratowo et al., 2022). Based on the N-Gain results, it can be seen that the increase in learning outcomes after using the e-module can refer to the N-Gain category which is divided into three, namely high if (g) ≥ 0.7; moderate if $0.3 \leq$ (g) < 0.7; and low if (g) < 0.3 (Hake, 1998). The following is the formula used in the analysis of the level of validity, analysis of student responses, and analysis of gain scores.

The formula for assessing the average validity score:

$$\%Validity = \frac{Score\ obtained}{Max\ Score\ x\ Number\ of\ validators} \times 100\% \quad (1)$$

Practical average score assessment formula:

$$\%Practicality = \frac{\sum Score\ Obtained}{Max\ Score\ x\ Number\ of\ Respondent} \times 100\% \quad (2)$$

N-Gain score analysis formula:

$$g = \frac{< \%Sf > - < \%Si >}{(100 - < \%Si) >)} \quad (3)$$

Description:
g = normalized gain score average
Sf = final score (post-test)
Si = initial score (pre-test)
100 = Maximal score

Through a series of development stages carried out in this research, it is hoped that the chemo-entrepreneurship-based chemistry practicum e-module product with a project-based learning model on the colligative properties of solutions material meets the aspects of validity, practicality, and effectiveness so that the product developed meets the criteria of validity, practicality, and effectiveness in supporting the chemistry learning process and improving student learning outcomes on the colligative properties of solutions material.

RESULT

Define Stage

The analysis of the define stage shows that chemistry learning on the colligative properties of solutions is still dominated by conventional teaching materials, resulting in less active student participation. The teaching materials used are still limited to textbooks and lack interactive learning media such as instructional videos or interactive quizzes. Furthermore, chemistry practicals are rarely conducted and are not linked to the application of chemical concepts in everyday life or entrepreneurship. Limited practical materials and incomplete laboratory equipment result in teacher-centered learning. The student analysis revealed that students are more interested in learning that involves practical work, the use of digital media, and contextual learning activities. Students also require teaching materials that can be studied independently, are interactive, easy to understand, and easily accessible through electronic media.

Colligative properties of solutions are a phase F chemistry topic in the Independent Curriculum taught in grade 12 of senior high school (SMA/MA). This material covers vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure of solutions. Colligative properties of solutions require conceptual understanding as well as practical activities to facilitate concrete understanding of the concepts learned. The concept of freezing point depression can be applied to homemade ice cream practicums, the concept of boiling point elevation can be applied to syrup and candied fruit production, and the concept of osmotic pressure can be applied to the preservation or production of candied fruit. These concepts are relevant to everyday life and can be integrated with the chemo-entrepreneurship approach because they relate to the development of simple products with economic value and business opportunities. Therefore, the material on colligative properties of solutions is considered suitable for development in the form of a chemo-entrepreneurship-based e-module for practicum guidance.

Previous research supporting this development, including that of Hafizatul Ilma et al. (2022), demonstrated that electronic practicum guidance can increase student engagement and facilitate practicum implementation through interactive digital teaching materials. Furthermore, research by Nurhadiana and Fitri F. (2024) demonstrated that interactive chemo-entrepreneurship-based e-modules can facilitate a more engaging and contextual understanding of chemistry concepts and increase student engagement during the learning process. Another relevant study was conducted by Ibrahim and Sutiani (2025), who developed a chemistry e-module based on project-based learning. The results of the study showed that the developed e-module received a positive response from students and was suitable for use as a teaching material to support student-centered chemistry learning.

Based on the results of the initial and final analysis, student analysis, assignment analysis, concept analysis, learning objective analysis, and chemo-entrepreneurship analysis, as well as previous research, it is necessary to develop an e-module for project-based learning lab guidance with a chemo-entrepreneurship approach on the topic of colligative properties of solutions. The developed e-module features interactive presentation, complemented by learning videos, interactive quizzes, and project-based lab activities involving the creation of simple products related to the concept of colligative properties of solutions. Furthermore, the e-module can be accessed electronically through the Heyzine platform, making it more flexible for use in learning. The integration of the project-based learning model and the chemo-entrepreneurship approach is expected to facilitate conceptual understanding through contextual project and lab activities while simultaneously fostering students' creativity, critical thinking skills, and entrepreneurial spirit.

Design Stage

The design stage aims to prepare a product design that is developed in accordance with the needs identified in the define stage (Putri et al., 2024). The chemistry lab e-module format is structured according to the lab guide components, which include the lab title, lab objectives, theoretical basis, tools and materials, lab procedures, observation sheets, and evaluation questions to measure students' understanding of the colligative properties of solutions. The e-module is also tailored to the chemo-entrepreneurship approach and project-based learning model. The e-module structure consists of a cover, foreword, table of contents, introduction, material description, entrepreneurship concept, introduction to chemo-entrepreneurship, inspirational stories, project flow, lab activities, and a conclusion. Lab activities include making syrup, gummy candies, ice cream, and sweets from natural ingredients, integrated with project-based learning syntax: problem orientation, project planning, scheduling, monitoring and guidance, presentation of results, and evaluation and reflection (Suradika et al., 2023).

The e-module is developed digitally in A4 size (21 × 29.7 cm) portrait orientation using Times New Roman and Georgia fonts. The font size used was 14 bold for chapter titles, 12 bold for subchapters, and 12 for the body text. The design process began with storyboarding, followed by the creation of an initial design (draft 1) using several supporting applications such as Canva, Adobe Photoshop, Microsoft Word 2010, Heyzine, Quizizz, and QR code software. The initial draft was then published on the Heyzine platform, making it accessible online through various electronic devices using the provided link.

Development Stage

According to Nafiyanto and Pebriana (2023), the development stage is the stage for producing a developed product, which involves two steps: expert appraisal, followed by revisions, and developmental testing. At this stage, the practical e-module was developed and refined based on expert validation results before being piloted with students.

All e-module components were presented in flipbook format via the Heyzine platform, allowing flexible access using any internet-connected electronic device. Several sections of the chemistry lab e-module are as follows:

Initial Section

The initial section of the e-module consists of the cover and introduction. The cover contains the title, grade level, author's identity, and illustrations. The introduction includes the foreword, table of contents, user instructions, learning outcomes, learning objectives, and a concept map. The initial section of the e-module is shown in Figure 1.

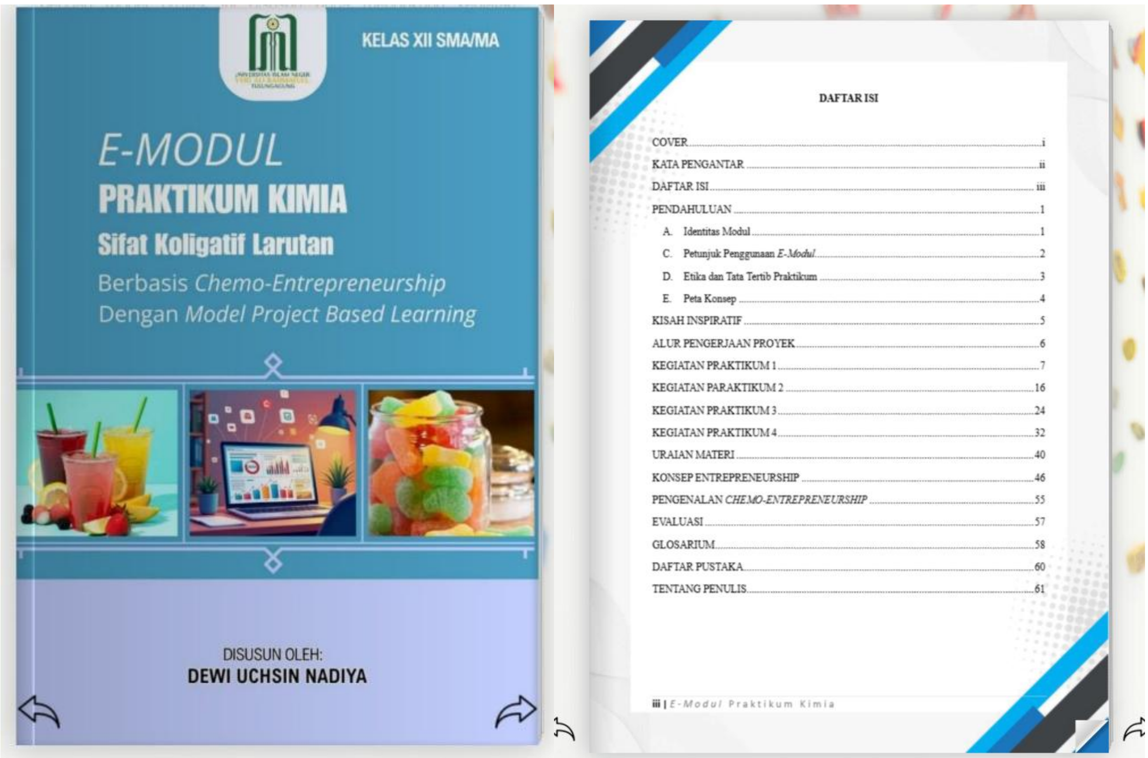


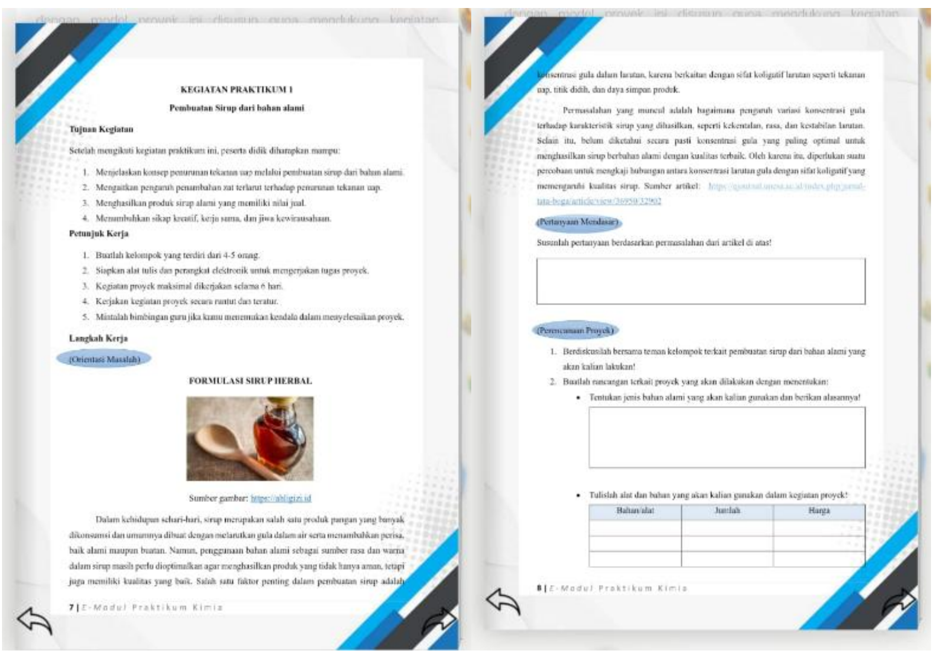
Figure 1. Initial view of the e-module

Contents of the e-practicum module

The chemistry practicum e-module includes inspirational stories, material on colligative properties of solutions, an integrated project and chemo-entrepreneurship practical activities, practice questions, evaluations, a glossary, and a bibliography. The colligative properties of solutions are presented systematically and supplemented with supporting images, learning videos accessible via QR codes, supporting information on the application of concepts in everyday life, and interactive quizzes to help students understand the material. The material presentation is shown in Figure 2.

Figure 2. Display of colligative properties of solutions

In addition, the e-modules are designed according to the project-based learning syntax, which includes determining fundamental questions, designing projects, preparing schedules, implementing projects, testing results, and evaluating learning experiences, allowing students to be actively involved in the learning process (Suradika et al., 2023). The chemo-entrepreneurship approach is also applied at the project design stage through business opportunity analysis, determining product selling prices, calculating Break Even Points (BEP), and identifying SWOT (Strengths, Weaknesses, Opportunities, and Threats) (Natasya et al., 2025). The chemistry practicum activities using the project-based learning syntax and the chemo-entrepreneurship approach are presented in Figure 3.



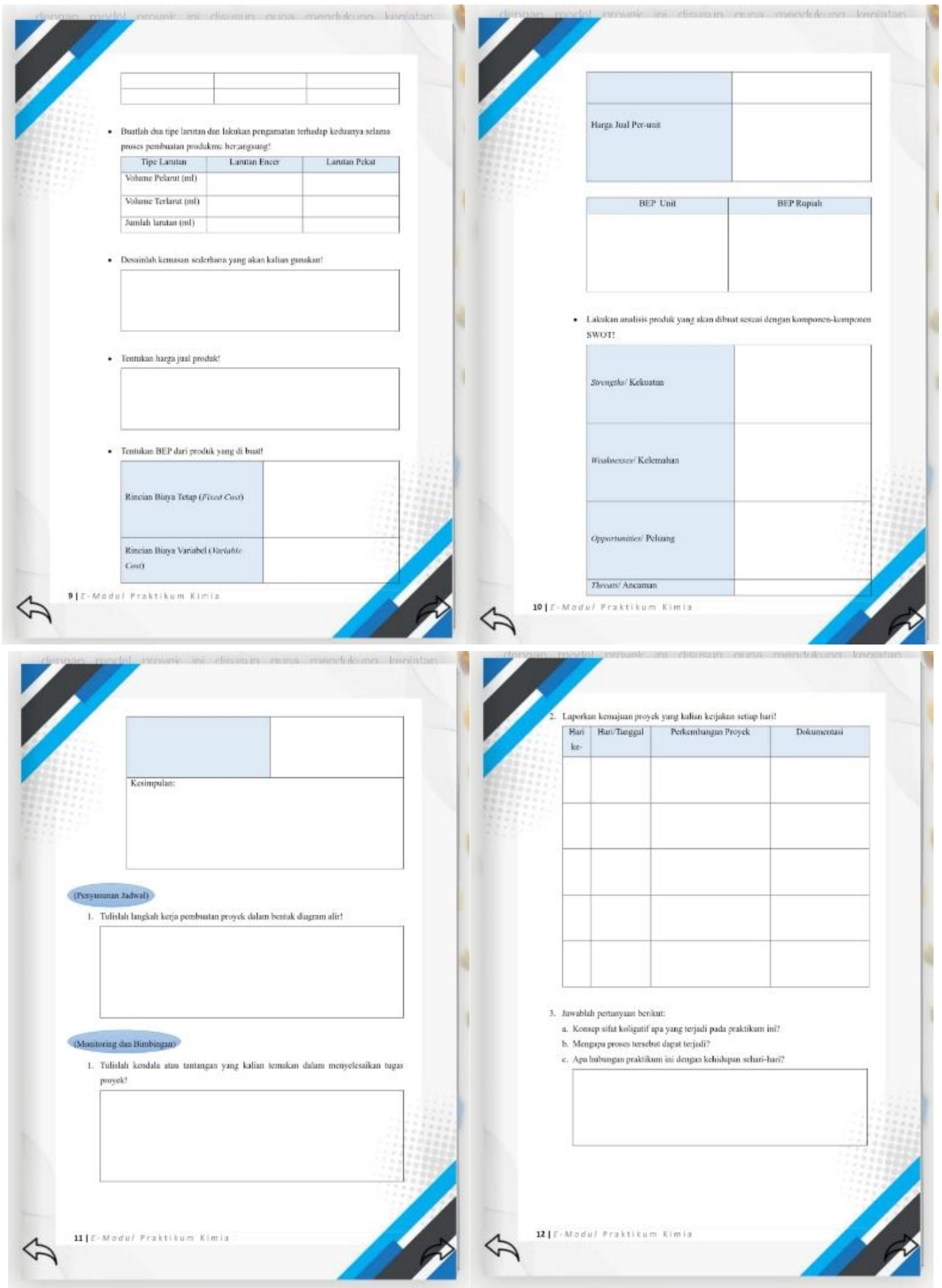


Figure 3. Display of chemistry practical activities

Presentation of Validity Test Data

The validation results from the material experts obtained an average of 83.28%, categorized as very valid. The high validity value indicates that the e-module has met the content, presentation, and language aspects. This is supported by the suitability of the material with the learning outcomes and learning objectives, systematic presentation of the material, and integration with the chemo-entrepreneurship approach and project-based learning model. In addition, the e-module is equipped with supporting components, such as user instructions, concept maps, images, videos, QR barcodes, and practice questions, and uses communicative language to facilitate students' understanding of the material. Although it has met the criteria, the validator provided several suggestions for product improvements. All of these suggestions were used as a reference in revising the product to improve the quality of the e-module. The validation results from the material experts are presented in Table 5, while the details of the suggestions and revision results are shown in Table 6.

Table 5. Results of material experts

Aspect	Validator 1 (%)	Validator 2 (%)	Mean (%)	Criteria
Content	86,67	77,78	82,22	Very Valid
Display	89,00	78,00	83,50	Very Valid
Languange	88,00	80,00	84,00	Very Valid
Mean			83,28	Very Valid

Table 6. Results of improvements according to the suggestions of the material expert validator

Before Revision

Contoh analisis SWOT

Bisnis "Manik-Manik Kreatif" merupakan usaha kerajinan tangan yang memproduksi manik-manik untuk aksesoris seperti gelang, kalung, dan gantungan kunci. Untuk mengembangkan usaha, dilakukan analisis SWOT dengan hasil sebagai berikut:

Strengths (Kekuatan)	*Weaknesses* (Kelemahan)	*Opportunities* (Peluang)	*Threats* (Ancaman)
Produk memiliki desain unik dan dapat dibuat sesuai selera konsumen	Proses pembuatan membutuhkan ketelitian dan waktu yang cukup lama	Minat terhadap aksesoris *handmade* semakin meningkat	Banyak produk aksesoris pabrikan dengan harga lebih murah
Bahan baku mudah diperoleh dan relatif murah	Produksi masih terbatas karena dikerjakan secara manual	Dapat dipasarkan melalui media sosial dan *marketplace*	Perubahan tren aksesoris yang cepat

After Revision

Contoh analisis SWOT

Pembuatan asinan buah merupakan penerapan sifat koligatif larutan berupa tekanan osmotik, di mana larutan garam dapat menyebabkan produk lebih awet dan bercita rasa khas serta berpotensi sebagai peluang usaha. Berikut merupakan hasil analisis SWOT dari produk asinan buah:

Strengths (Kekuatan)	*Weaknesses* (Kelemahan)	*Opportunities* (Peluang)	*Threats* (Ancaman)
Bahan baku mudah diperoleh dan murah	Mudah rusak jika penyimpanan kurang baik	Dapat dikreasikan dengan berbagai buah	Banyak produk asinan sejenis di pasaran
Proses pembuatan sederhana dan tidak membutuhkan waktu yang cukup lama	Produksi masih terbatas karena dikerjakan secara manual	Asinan digemari berbagai kalangan	Perubahan selera konsumen

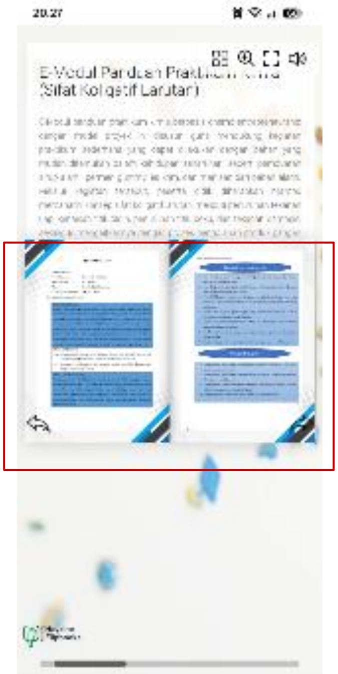
Entrepreneurship theory is associated with business in the chemical sector by giving examples of chemical products.

The media expert validation results obtained an average of 83.12% with a very valid category. The high validity value indicates that the e-module has met the graphic and operational aspects. This is supported by the proportional size and layout of the e-module, attractive and consistent cover and content design, the selection of colors, fonts, and illustrations that are appropriate to the material, and easy access to links, QR barcodes, and videos through various electronic devices. Nevertheless, the e-module was still revised based on suggestions and input from the validator to improve the product quality before the trial. The results of the media expert validation are presented in Table 7, while the validator's suggestions and input for product improvement are presented in Table 8.

Table 7. Media expert results

Aspect	Validator 1 (%)	Validator 2 (%)	Mean (%)	Criteria
Grafik	82,50	80,00	81,25	Very Valid
Operation	90,00	80,00	85,00	Very Valid
Mean			83,12	Very Valid

Table 8. Results of improvements according to the expert material validator's suggestions

Before Revision	After Revision
	
Arrange the display on your device so that it is comfortable to access and easy to read.	

Based on the validator's assessment, the developed e-practicum module was categorized as highly valid. All suggestions and input provided by the validator were followed up through a product revision process. Therefore, the chemo-entrepreneurship-based chemistry practicum e-module, using a project-based learning model on the colligative properties of solutions, was deemed suitable for testing with students and use in the learning process. These results support research by Anjani et al. (2022), which obtained a highly valid category for developing a simple practicum-based chemistry learning module. According to the Ministry of National Education (2008), the high validity score indicates that the e-module meets the appropriateness of content, presentation, language, and graphics, making it suitable for use in learning.

Presentation of Practicality Test Data

After the e-practicum module was declared valid by the experts, the next stage in the development phase was a limited trial with 36 students in grade XII-1. This trial aimed to obtain student responses to the developed e-practicum module. The students involved had previously studied the colligative properties of solutions, but the learning process was still conducted conventionally and had not yet utilized the chemo-entrepreneurship-based lab e-module with a project-based learning model. Therefore, a limited trial was conducted to determine the level of readability, ease of use, and student acceptance of the developed e-module.

Based on the student response questionnaire in Table 9, the e-module received a rating of 85.48%, categorized as very practical. This high level of practicality indicates that the e-module is easy to use and supports the learning process. This is likely due to the e-module's attractive design, clear instructions, and project-based lab activities that help students understand the concept of colligative properties of solutions contextually. The systematic presentation of the material also facilitates independent learning, thereby increasing student motivation and engagement, especially during lab activities. These findings are supported by research by Muliati et al. (2024), which showed that the project-based lab module was categorized as very practical because it was easy to use, had clear instructions, and was able to assist students in carrying out learning and lab activities.

Table 9. Student responses

No.	Indicator	Percentage %	Criteria
1	Attracting students' interest	85	Very practical
2	Presented in color and with pictures	84,1	Very practical
3	Compliance with school materials	86,7	Very practical
4	Clarity of learning objectives	88,3	Very practical
5	Clarity of learning steps	85,8	Very practical
6	Clarity of questions	84,1	Very practical
7	Raising learning motivation	87	Very practical
8	Encourage problem solving	83,6	Very practical
9	Guiding critical thinking	80,2	Very practical
10	Contain *chemo-entrepreneurship*	89,7	Very practical
	Mean percentage %	85,48	Very practical

Effectiveness Test Data Presentation

The effectiveness test was conducted to determine improvements in student learning outcomes before and after using the e-practical module. The instrument used consisted of validated learning outcome questions in the cognitive domains C2–C5, which obtained an average score of 89.1, categorized as very valid. The trial involved 36 grade XII-1 students, administering a pretest before and a posttest after using the e-practical module. Improvements in learning outcomes were further analyzed using the N-Gain calculation. The N-Gain results can be seen in Table 10.

Table 10. N-gain results analysis

Pretest Mean	Posttest Mean	Gaps	N-Gain	N-Gain Percentage (%)	Categories
61,7	84,6	22,9	0,56	56%	Moderate/Quite Effective

Based on the results of a trial on 36 grade XII-1 students, the average pretest score of 61.7 increased to 84.6 in the posttest. The N-Gain test results showed an average score of 0.56, categorized as moderate, while the N-Gain percentage of 56% was categorized as moderately effective. These research findings are supported by Ramadhan et al. (2025), who reported that the use of a website-based e-module on sound waves achieved an N-Gain score of 0.58, categorized as moderate. These similar results indicate that e-modules as digital teaching materials can help improve student understanding and learning outcomes through interactive and systematic presentation.

The moderately effective category indicates that e-modules can improve student learning outcomes through presentation of material integrated with practical activities, a chemo-entrepreneurship approach, and a project-based learning model. Furthermore, the use of videos, images, QR codes, and interactive practice questions helped students grasp the concept of colligative properties of solutions more easily. This aligns with Mayer's (2009) Cognitive Theory of Multimedia Learning, which states that presenting information through a combination of text and multimedia can improve student understanding. However, the improvement in learning outcomes remains moderate due to differences in initial abilities and student characteristics.

CONCLUSION

Based on the results of the research that has been conducted, teaching materials in the form of e-modules for chemical practicums based on chemo-entrepreneurship with a project-based learning model on the colligative properties of solutions developed in this study have been proven to be valid, practical, and effective to be used as supporting teaching materials for chemical practicum activities. This research provides a contribution in the form of alternative teaching materials for practicums that integrate entrepreneurial aspects into chemistry learning, so that students not only understand the concept of colligative properties of solutions theoretically, but are also trained to relate these concepts to business opportunities and the economic value of chemical products in everyday life. By utilizing the heyzine platform, this e-module also offers a practical contribution in the form of flexible and easily accessible digital teaching materials, so that it can be a reference for teachers in developing similar teaching materials for practicums on other chemical materials that are oriented towards strengthening scientific literacy while fostering students' entrepreneurial spirit.

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